5th International Exergy, Life Cycle Assessment, and Sustainability Workshop & Symposium (ELCAS-5)
9 - 11 July, 2017, NISYROS - GREECE

Exergetic analysis of renewable Fischer-Tropsch fuels production from biomass, CO2 and electricity

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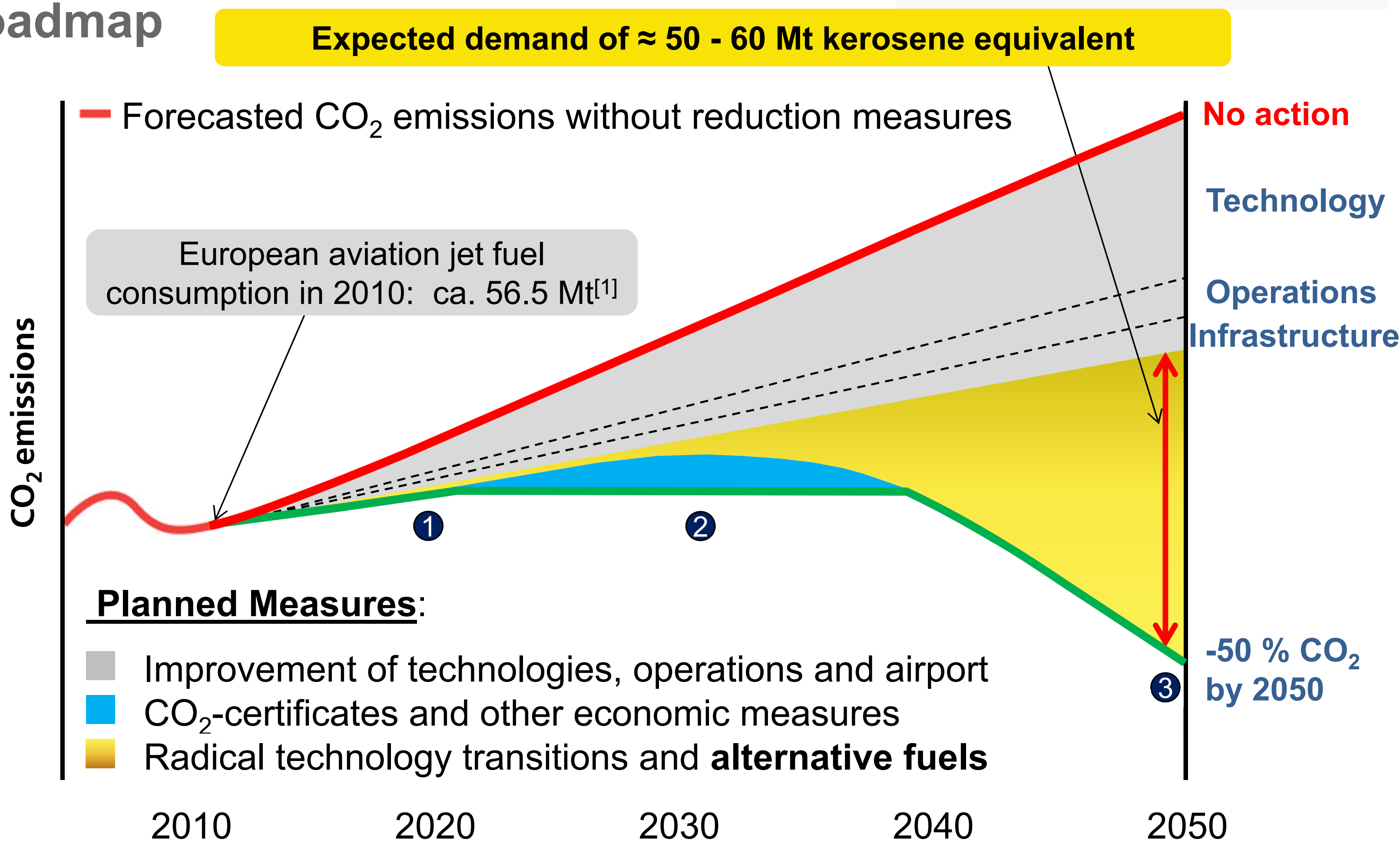
IATA Technology Roadmap

4. Edition, June 2013

Main goals:

1. Improvement of fuel efficiency about 1,5 %p.a. until 2020
2. Carbon-neutral growth from 2020
3. Potential CO_2 emissions reductions by 2050



[1] FuelsEurope "Statistical Report" 2010

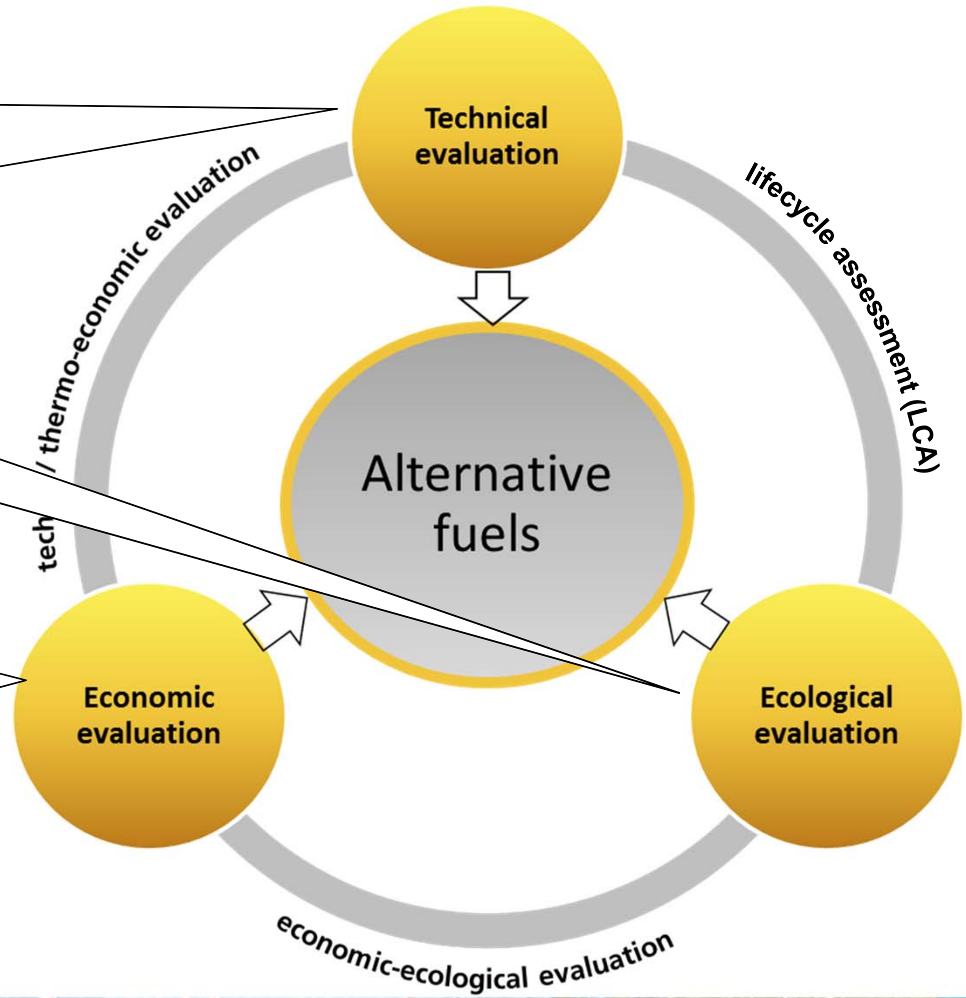
Source: iata.org

Applied methodology for fuel evaluation

Technical evaluation – focus on:

Ecological evaluation – focus on:
- CO_2-footprint of produced fuels
- CO_2-abatement costs

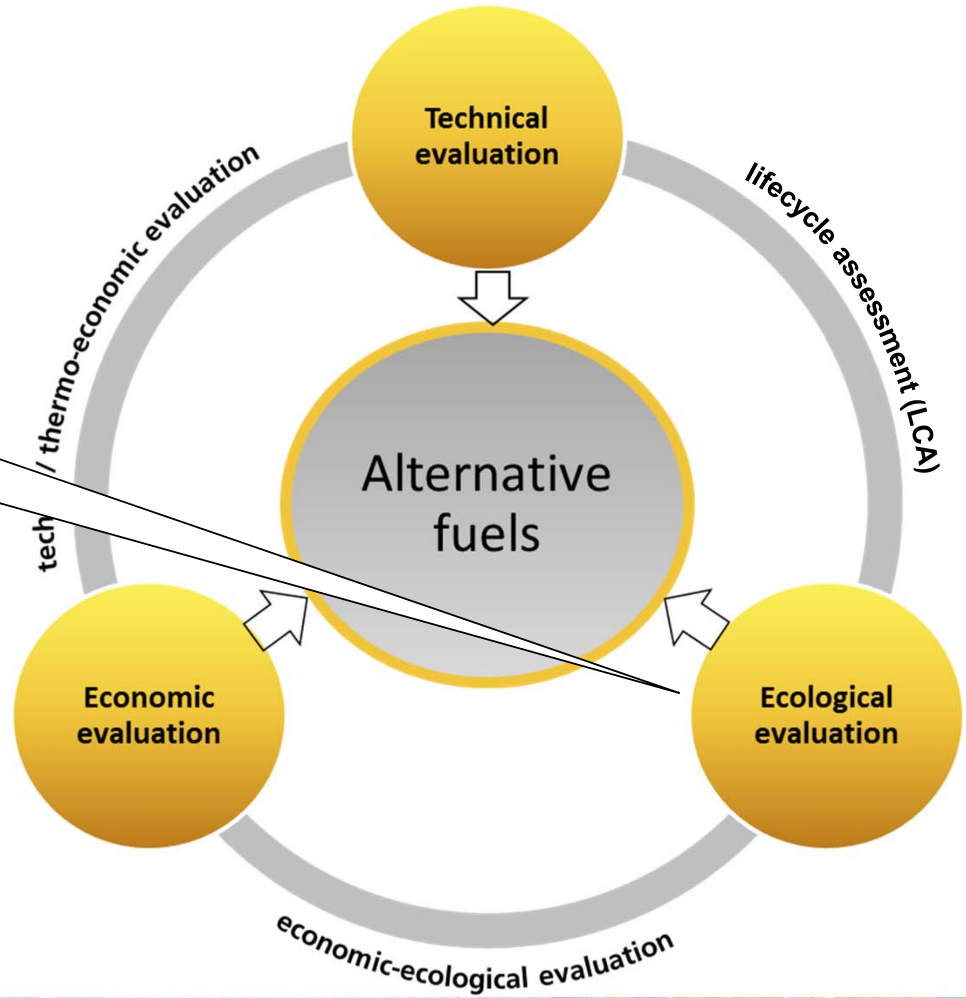
Economic evaluation – focus on:
- Production costs (CAPEX, OPEX, NPC)
- Sensitivity analysis
- Identification of cost reduction potentials (exergoeconomic evaluation)



Applied methodology for fuel evaluation

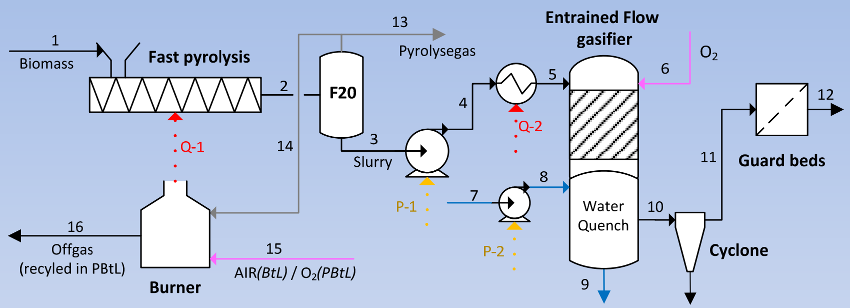
Ecological evaluation – focus on:

- ➢ CO_2-footprint of produced fuels
- ➢ CO_2-abatement costs



Methodology – exergy analysis

Process Simulation ⟷ **Exergy Analysis**



- Includes all important equipment such as pumps/HEX/Reactors
- Physical exergy ${E_x}^{Ph}$ available in Aspen Plus for every material stream

- Direct link between Aspen and TEPET
- Calculation of chemical exergy ${E_x}^{Ch}$
- Automated exergy analysis
- (planned) exergoeconomic optimization

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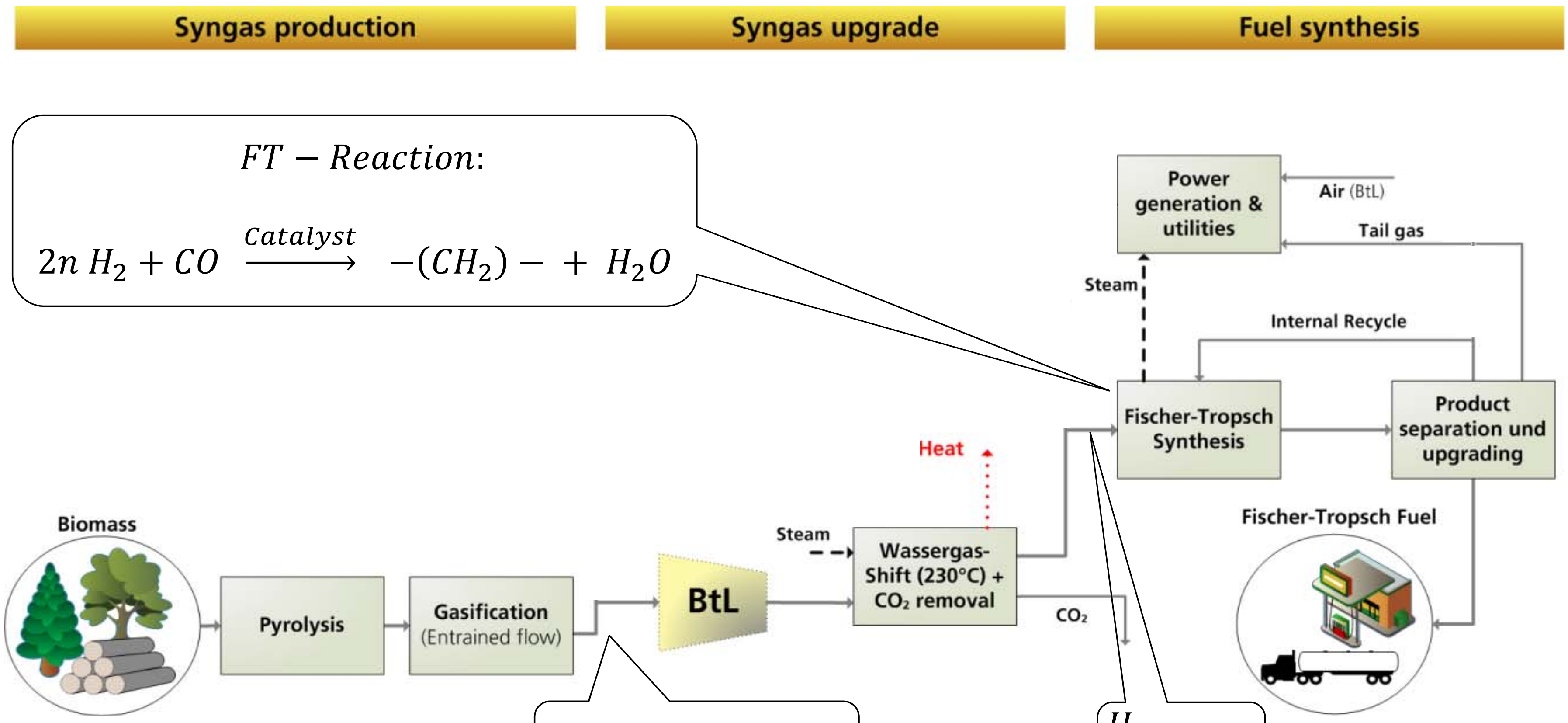
Multiple options for FT-fuels from biomass, power and CO_2

FT-fuel from Biomass – Biomass-to-Liquid (BtL)



$FT - Reaction:$

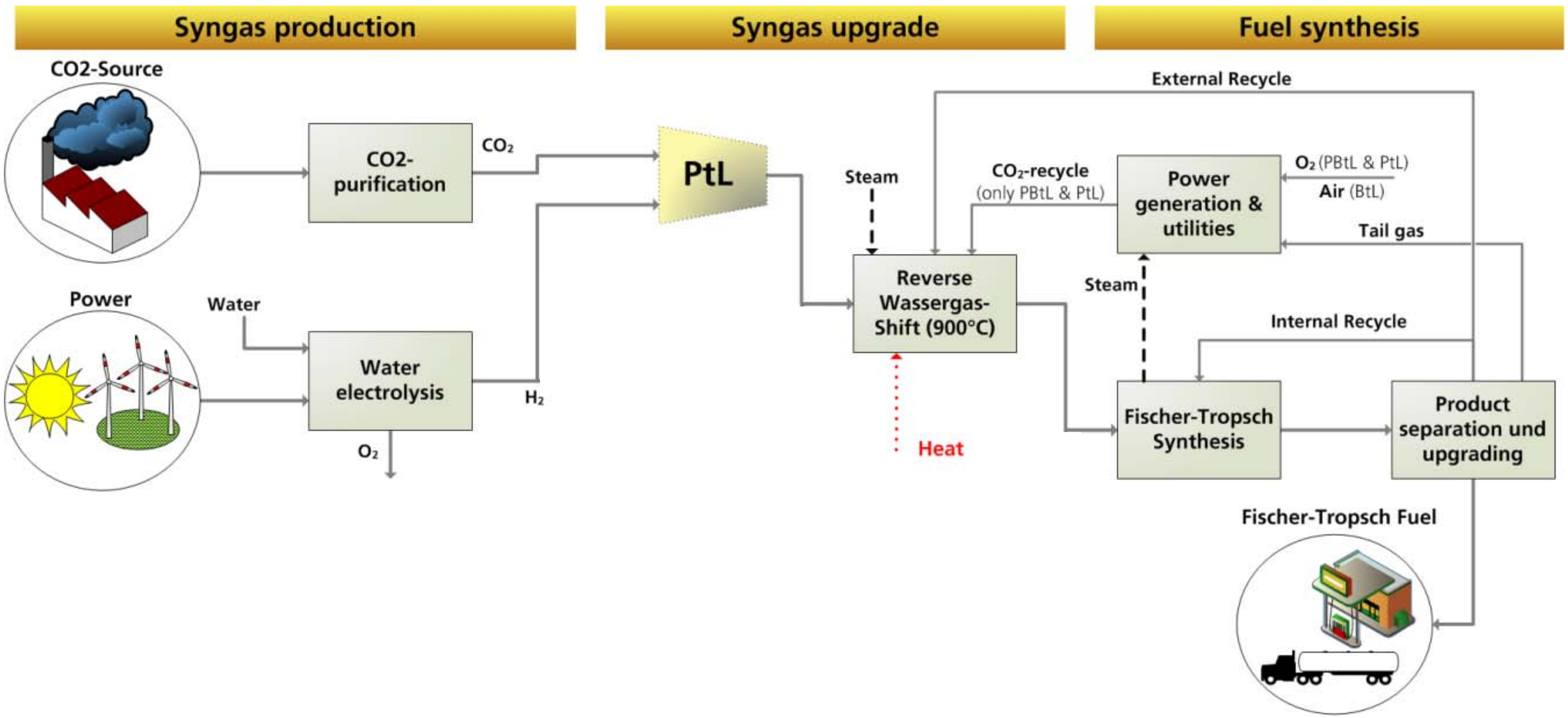
$$2n\, H_2 + CO \xrightarrow{Catalyst} -(CH_2)- + H_2O$$

$$H_2, CO, CO_2, H_2O$$

$$\frac{H_2}{CO} \approx 2$$

Multiple options for FT-fuels from biomass, power and CO_2

FT-fuel from Power and CO_2 – Power-to-Liquid (PtL)



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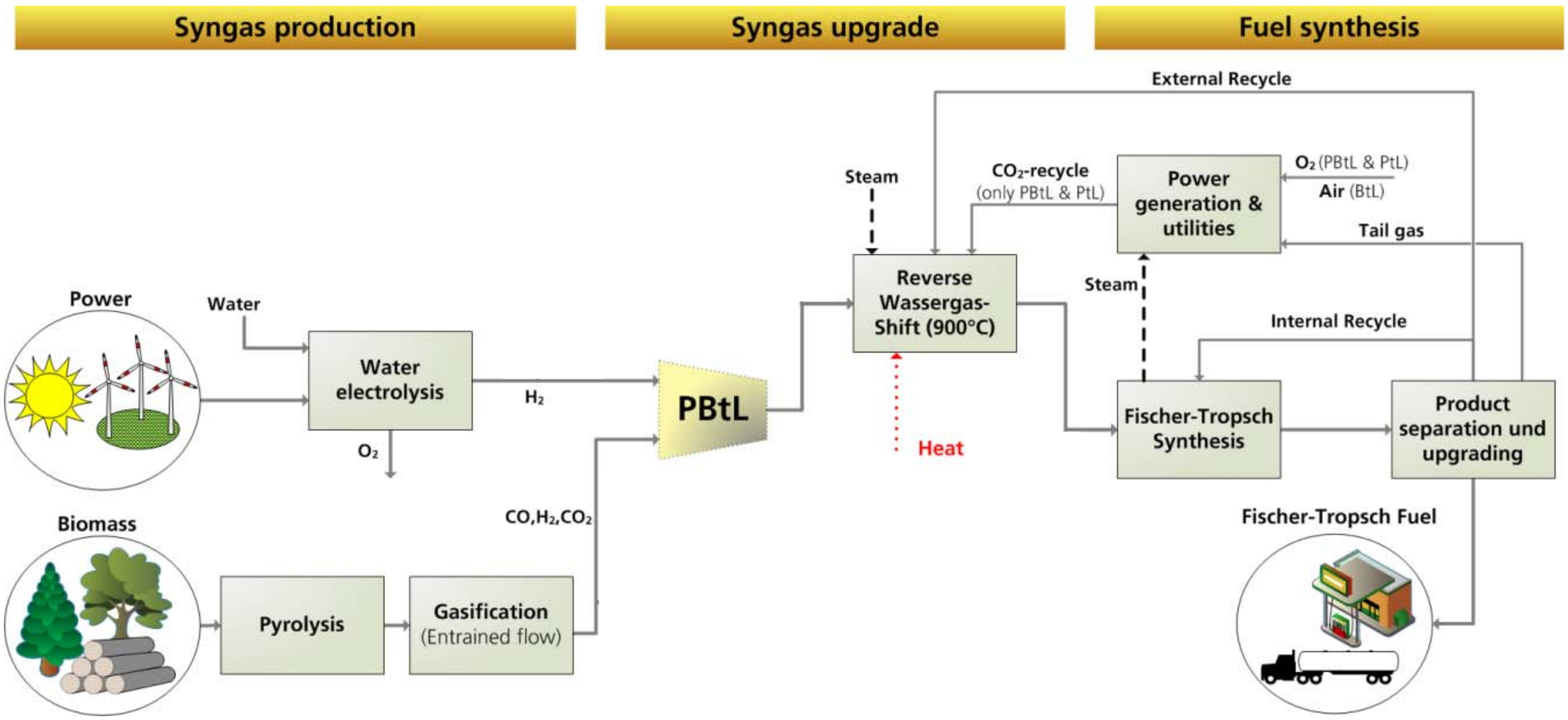
Multiple options for FT-fuels from biomass, power and CO_2

FT-fuel from Power and Biomass – Power&Biomass-to-Liquid (PBtL)



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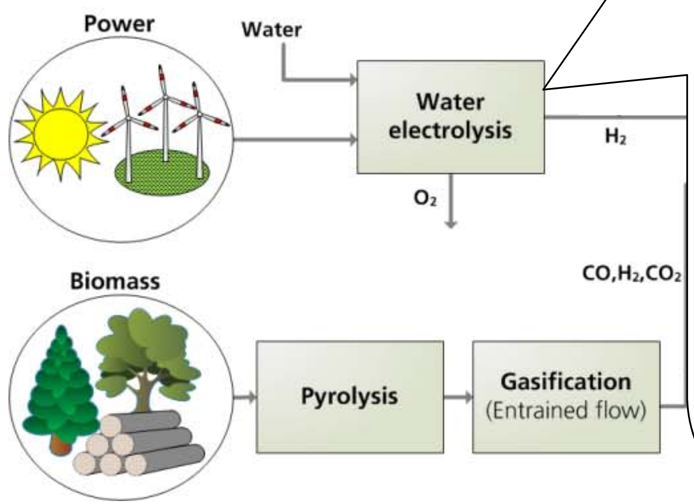
Multiple options for FT-fuels from biomass, power and CO_2

FT-fuel from Power and Biomass – Power&Biomass-to-Liquid (PBtL)

Syngas production | **Syngas upgrade** | **Fuel synthesis**



Main process section

Fuel exergy: $\dot{E}_{F,1}$ … $\dot{E}_{F,j}$

Product exergy: $\dot{E}_{P,1}$ … $\dot{E}_{P,k}$

Exergy destruction within section

$$\dot{E}_D = \sum_{i=1}^{j} \dot{E}_{F,i} - \sum_{i=1}^{k} \dot{E}_{P,i} - \sum_{i=1}^{l} \dot{E}_{L,i}$$

$\sum_{l} \dot{E}_{L,l}$ *Exergy losses*

$$\varepsilon = \frac{\sum \dot{E}_P}{\sum \dot{E}_F} \quad , \quad \gamma_D = \frac{\dot{E}_D}{\sum \dot{E}_F} \quad , \quad \gamma_L = \frac{\dot{E}_L}{\sum \dot{E}_F}$$

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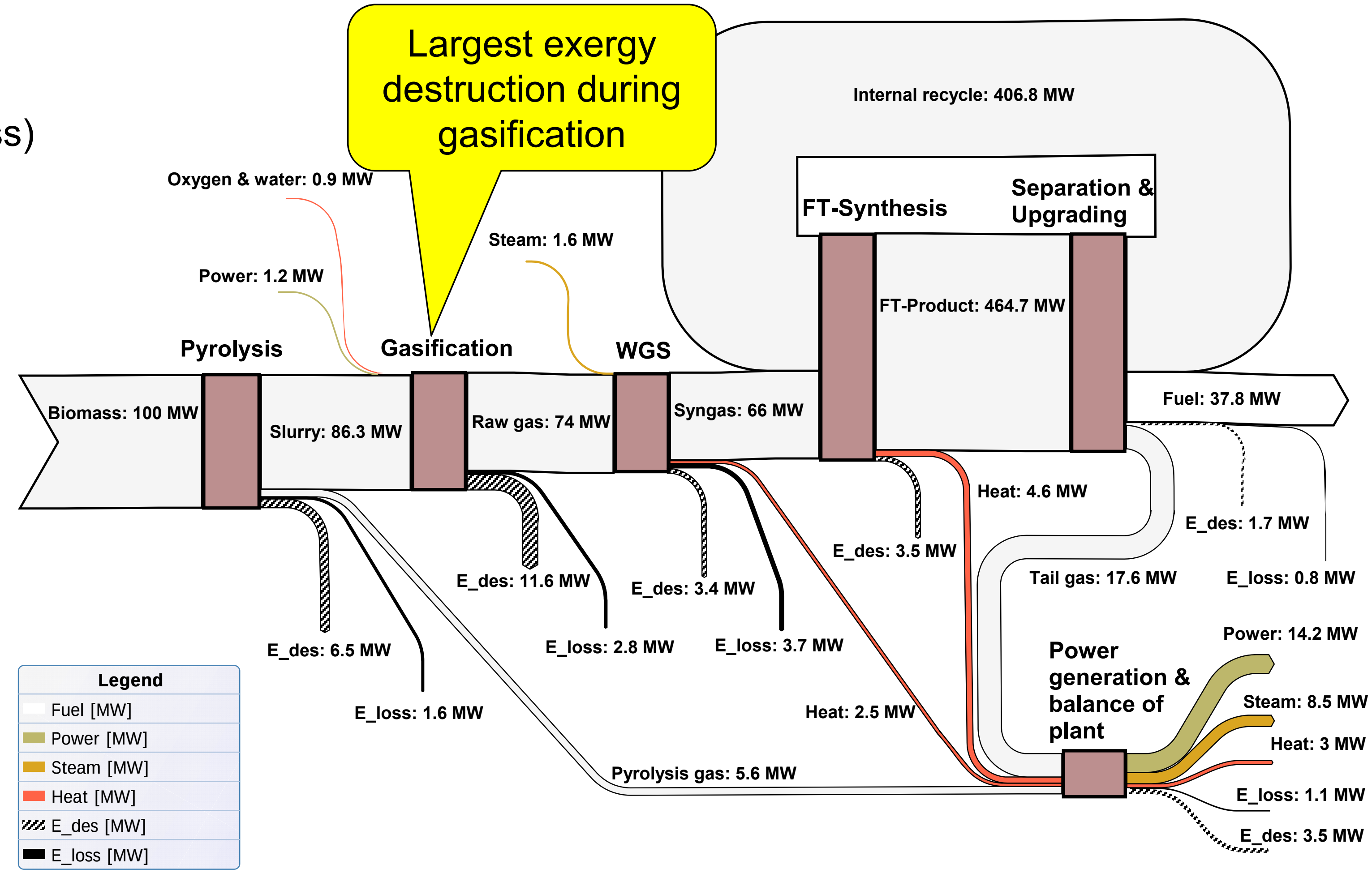
Exergy flows - Biomass-to-Liquid

Exergy input:
100 MW (Biomass)



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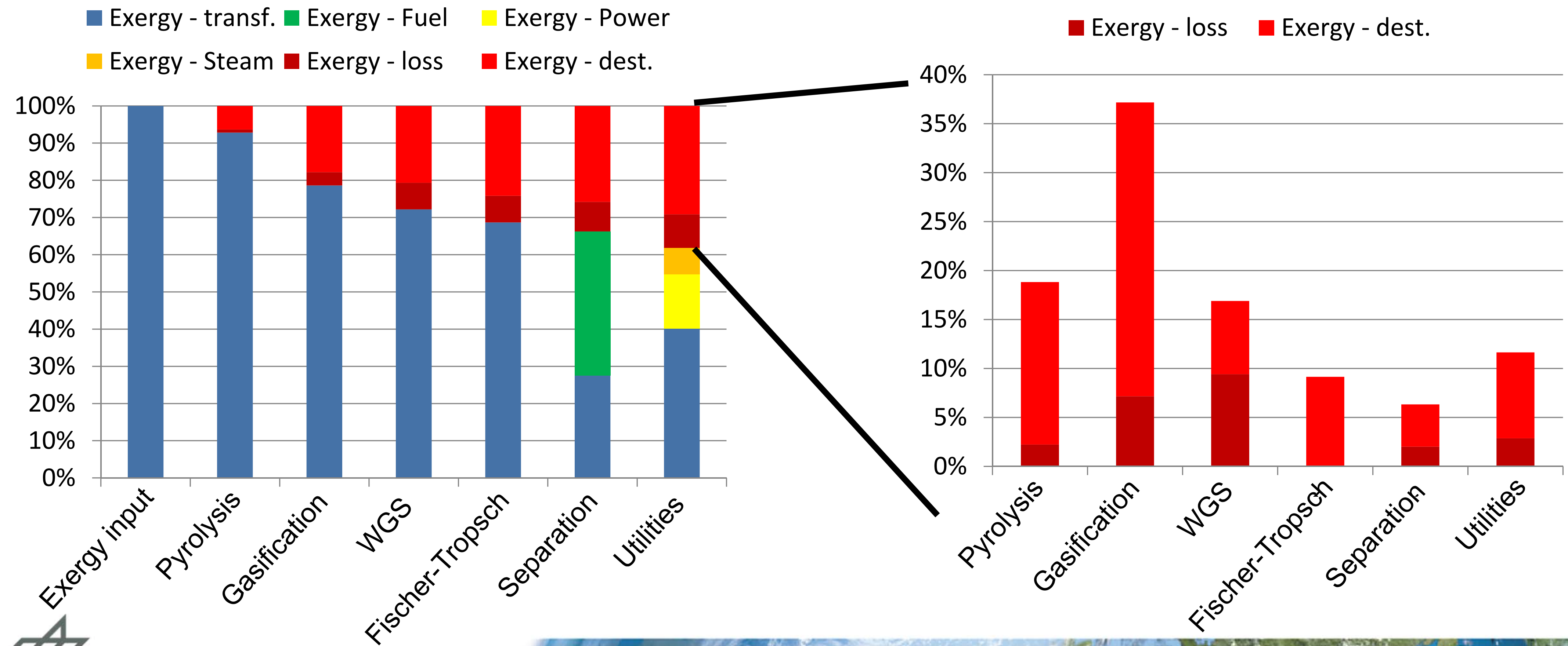
Exergy flows - Biomass-to-Liquid

$$\gamma_{D,sys} = \frac{\dot{E}_{D,section}}{\sum \dot{E}_D} \quad , \quad \gamma_{D,sys} = \frac{\dot{E}_{D,section}}{\sum \dot{E}_D}$$



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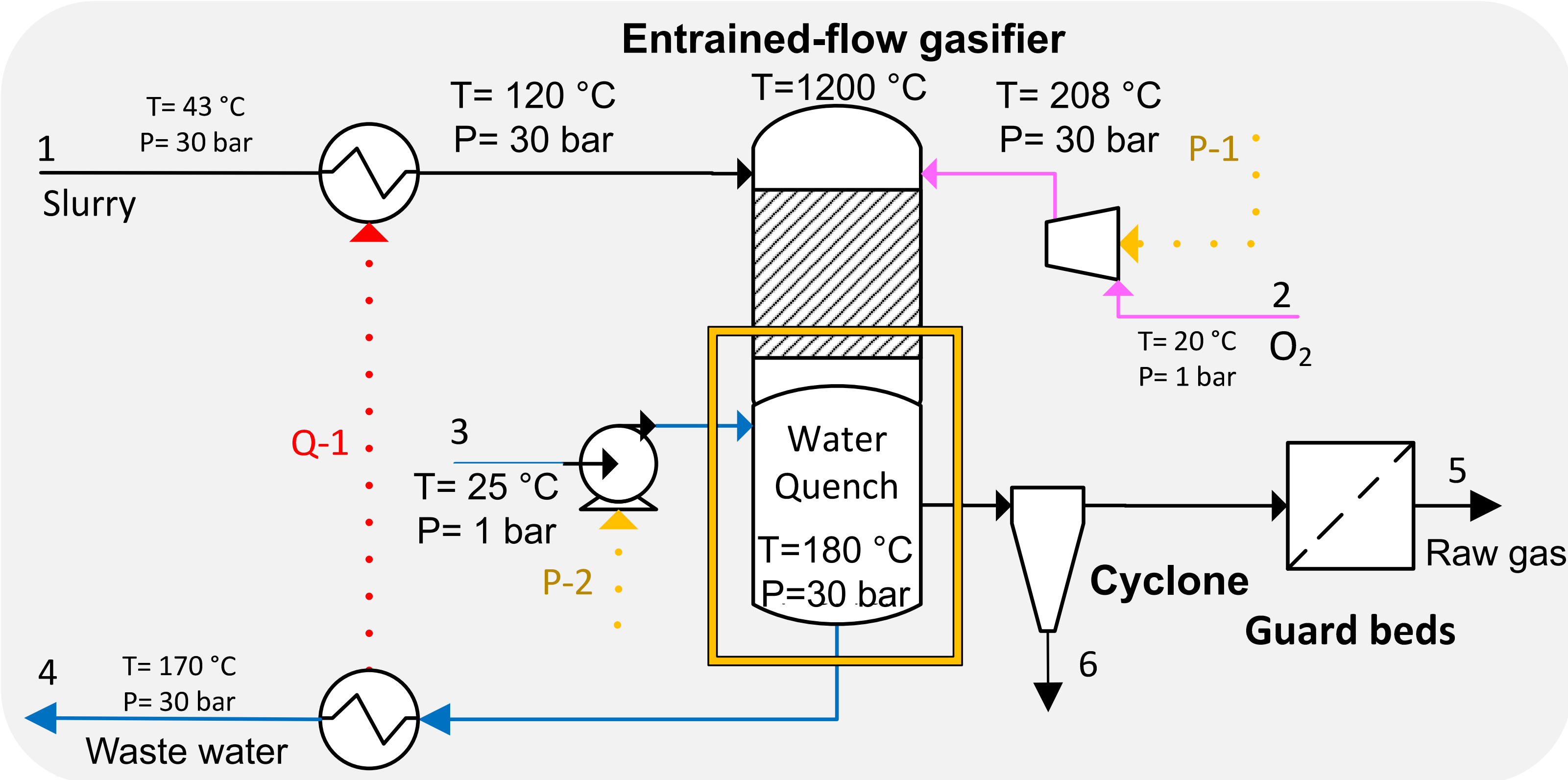
Detailed exergy analysis of gasification section

Water quench responsible for:

- **87 %** of exergy destruction within gasification section
- **35 %** of total exergy destruction within system

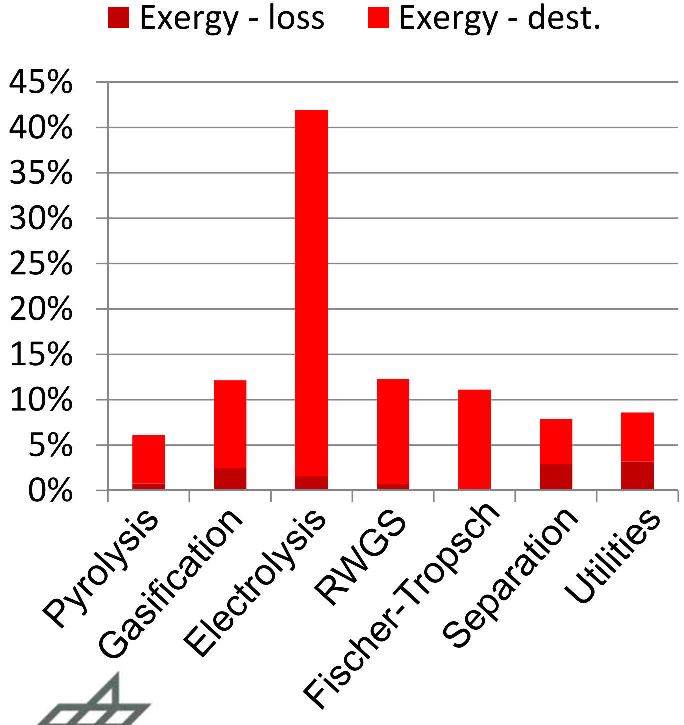
Promising alternatives:

- Hot gas cleaning
- Change of gasifier technology

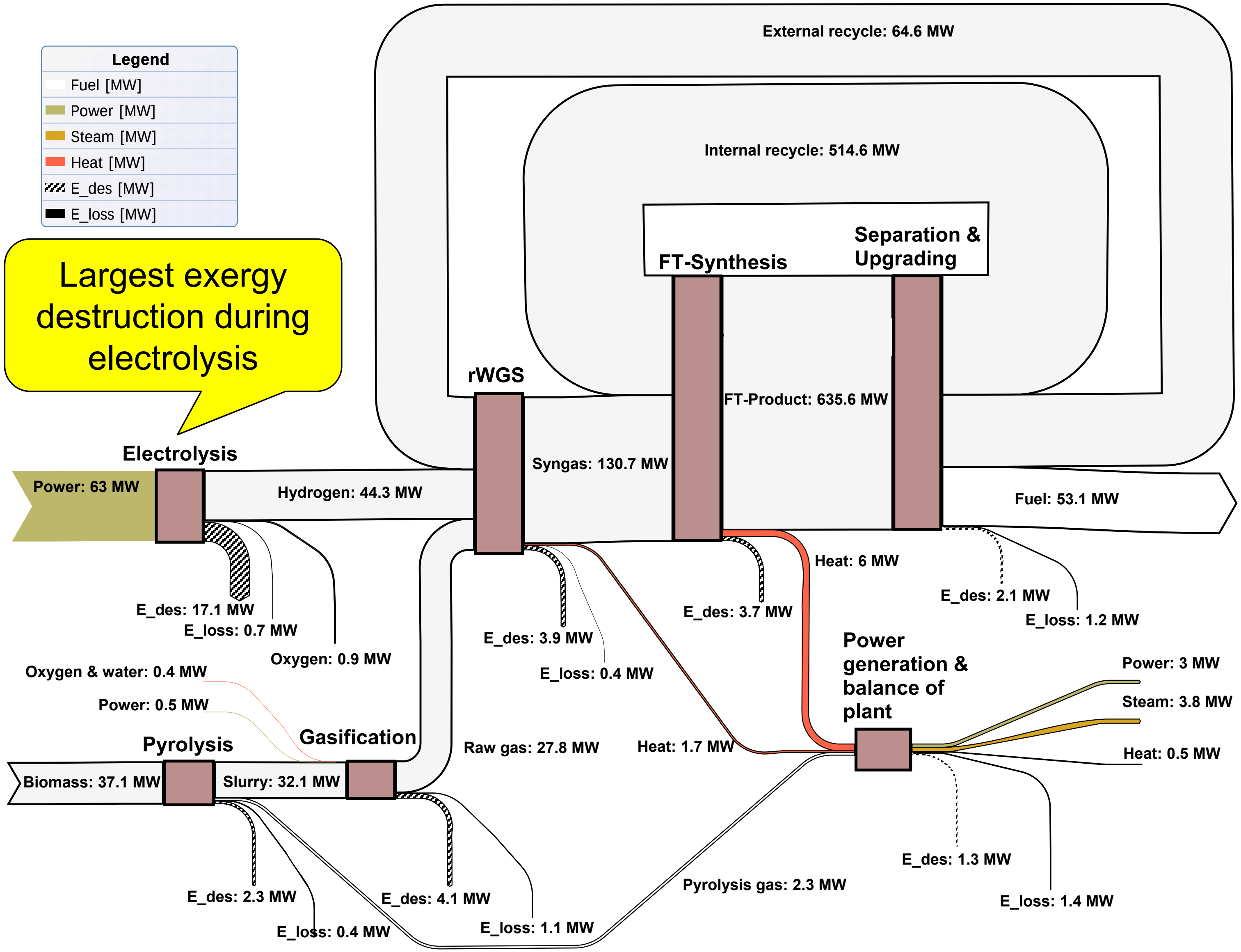


Exergy flows –PBtL

Exergy input:
37.1 MW (Biomass)
63 MW (Power)



Largest exergy destruction during electrolysis



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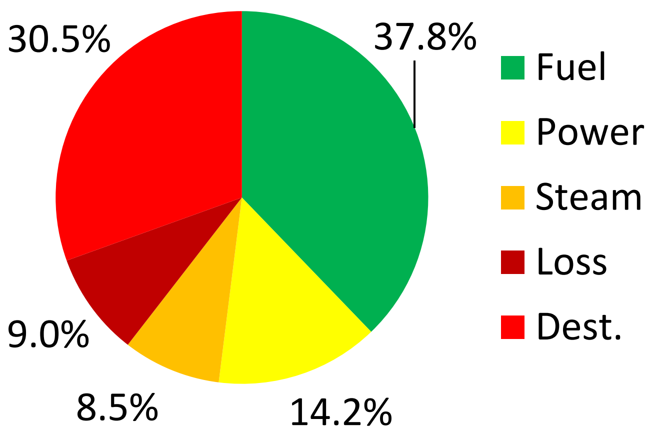
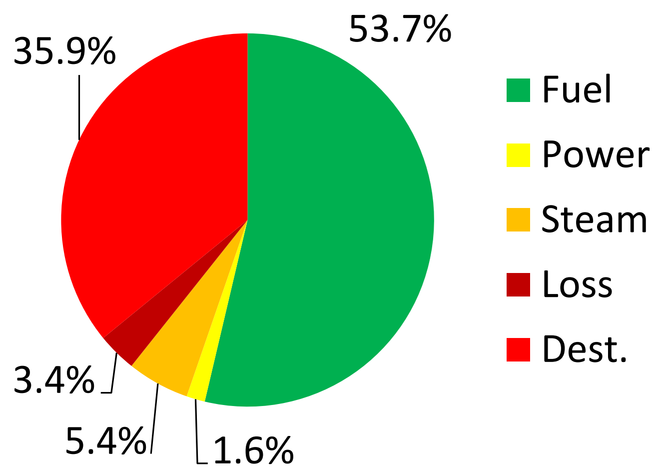
Result of exergy analysis

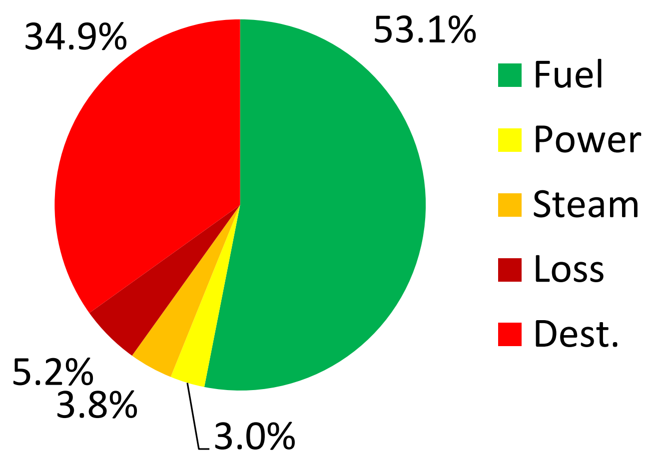
BtL



PtL



PBtL



Model	BtL	PtL	PBtL
ε_{fuel}	37.8 %	53.7 %	53.1 %
ε_{total}	63.5 %	61.2 %	60.4 %
Source of highest exergy destruction	gasification	electrolysis	electrolysis

Conclusion

- High demand of alternative fuels in order to fulfill CO_2-reduction targets -> especially with regard to the aviation sector
- DLR has developed a methodology to evaluate fuel production pathways
- Results of the presented case study:
  - Exergy efficiency of fuel production in the range of 37- 54 %
  - Most exergy destruction occurs during syngas production -> Technology shift may increase system efficiency significantly

    Promising options: BtL- Hot gas cleaning

    PtL- High temperature electrolysis (SOEC)

Outlook

- Applying fuel evaluation methodology on other renewable fuel production concepts
  - Butanol
  - Methanol-to-Gasoline
  - HEFA
  - Solar-Fuels
  - etc.

- Economic optimization (Exergoeconomic analysis/optimization)

- Lifecycle assessment
  - CO_2-footprint
  - CO_2-abatement cost

- Application of exergy and exergoeconomic analysis on other thermo-chemical processes
  - DLR-Project IsEN (Isentropic energy storage)

Other options for „green“ aviation?

Gossamer Albatross?

Crossing of the English Channel between Folkestone and Cap Gris-Nez by Bryan Allen on 12. June 1979

- Distance: 35.8 km
- Travel time: 2:49 hours

This corresponds to:

Flight from Stuttgart (STR)
➔ Kos (KGS): 1.970 km
Calculated flight time: **155 hours (6.5 days)**

Source: https://de.wikipedia.org/wiki/Gossamer_Albatross

THANK YOU FOR YOUR ATTENTION!

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Example: Process simulation Flowsheet (PtL)